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Kudo et al.

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(54) **MULTI-OPTICAL-PATH PHOTOELECTRIC SAFETY APPARATUS**

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(51) **Int. Cl.**[7] **H01J 40/14**
(52) **U.S. Cl.** **250/221**; 340/556
(58) **Field of Search** 250/221; 340/552, 340/555–557

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,704,396	A	11/1972	MacDonald	
4,249,074	A	2/1981	Zettler et al.	
5,233,185	A *	8/1993	Whitaker	250/222.1
5,243,183	A *	9/1993	Barron et al.	250/222.1
6,218,940	B1 *	4/2001	Rejc et al.	340/556
6,624,751	B2 *	9/2003	Haberer et al.	340/555
6,737,970	B2 *	5/2004	Wuestefeld et al.	340/552

FOREIGN PATENT DOCUMENTS

DE	23 43 096	A	3/1975
DE	44 22 497	A	1/1996

* cited by examiner

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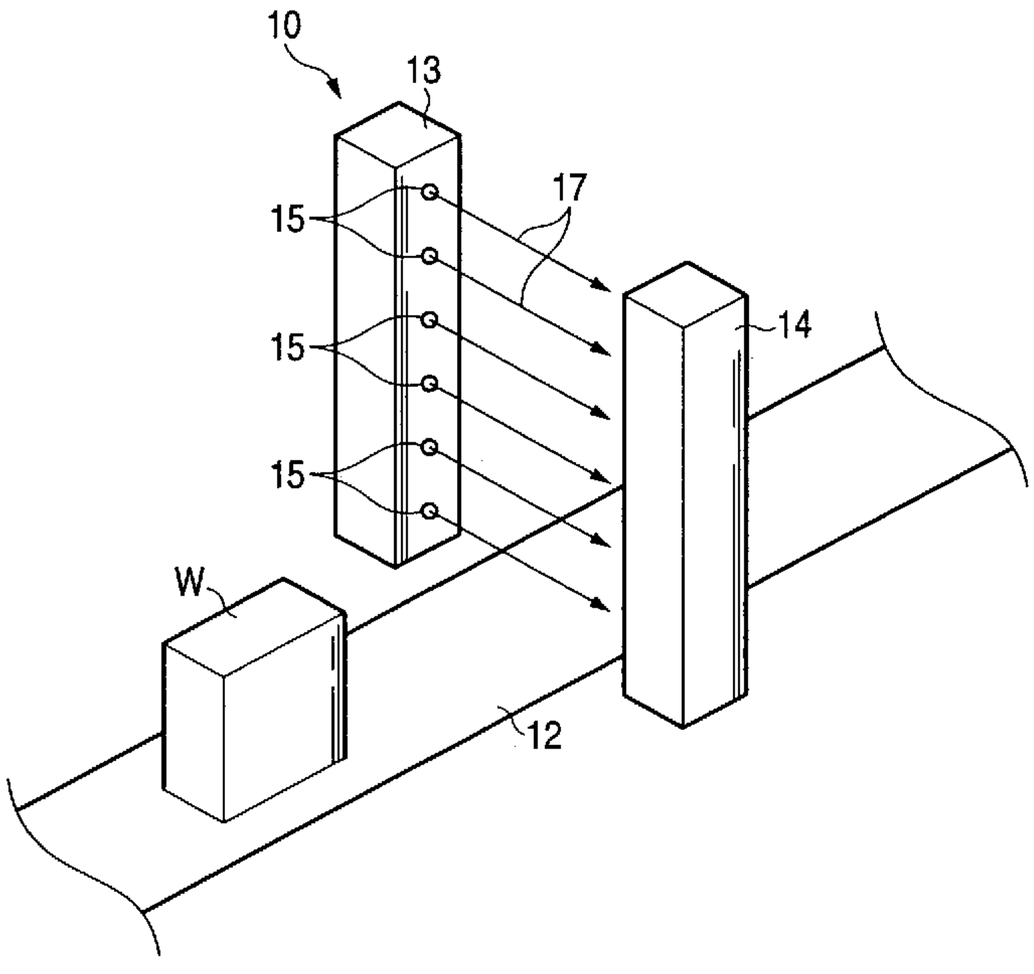
(57) **ABSTRACT**

A multi-optical-path photoelectric safety apparatus is provided that has a light emitting unit, a light receiving unit and a control unit for controlling each optical path. A light block substance sensing function for a multi-optical-path light curtain is also provided to sense an object between the light emitting unit and the light receiving unit. A muting area setting unit is also provided that can be taught how to set an area for exerting a muting function. The muting function can be provided only in a partial area of the light curtain by using the muting area setting unit.

13 Claims, 15 Drawing Sheets



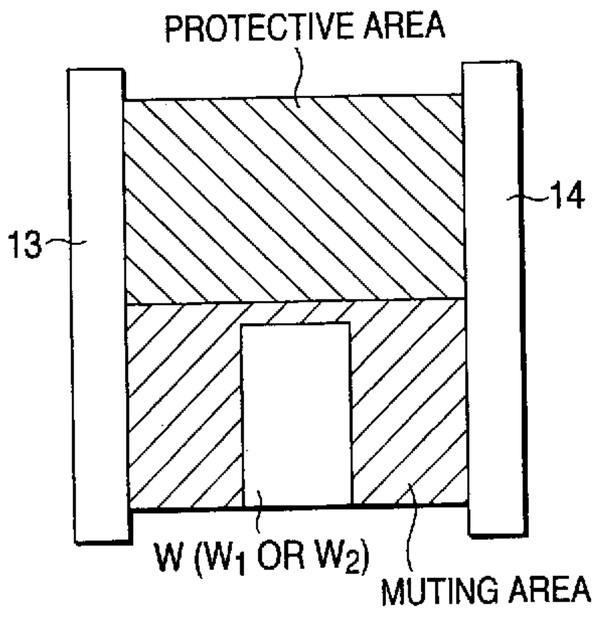


FIG. 1

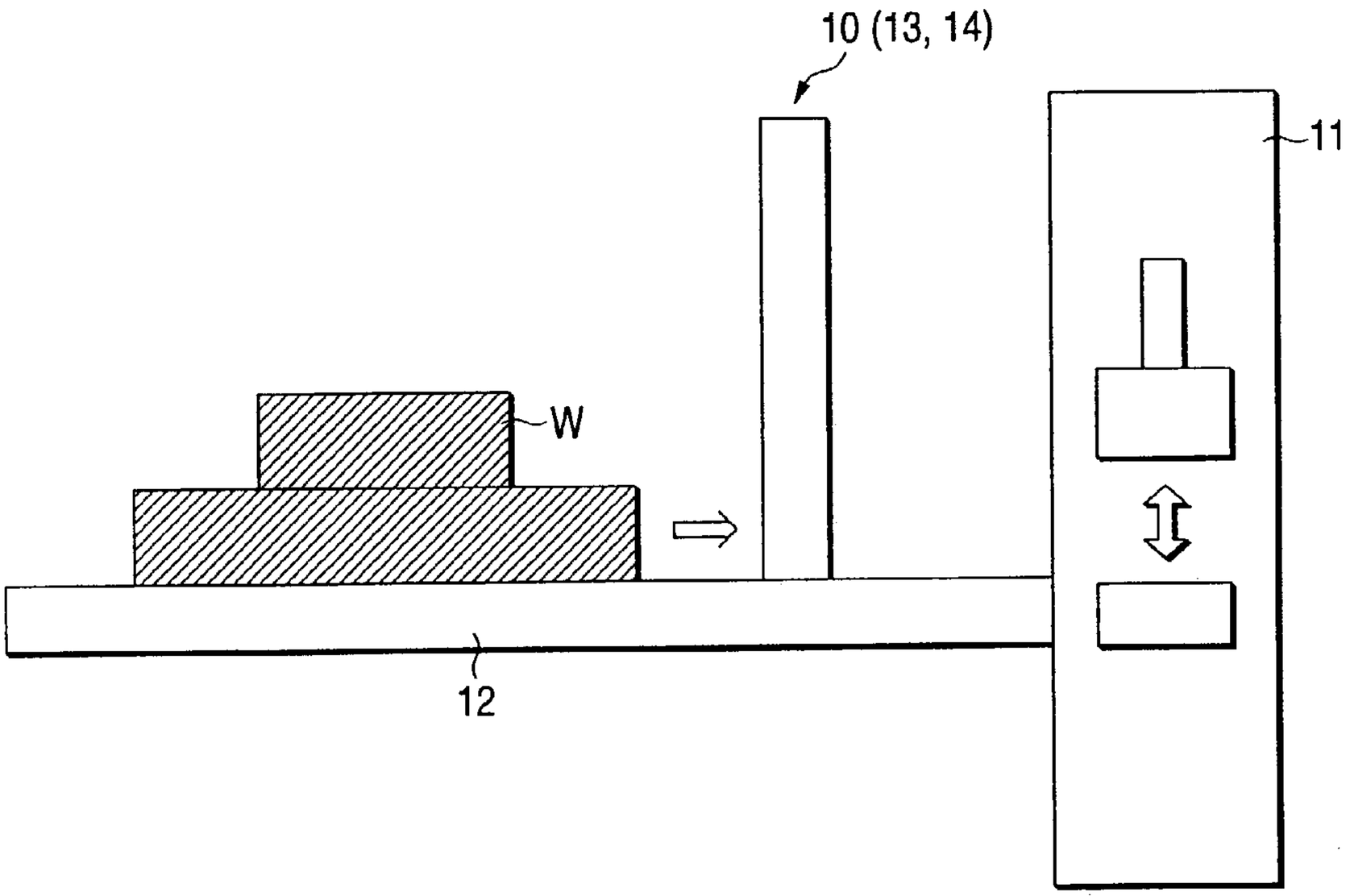


FIG. 2

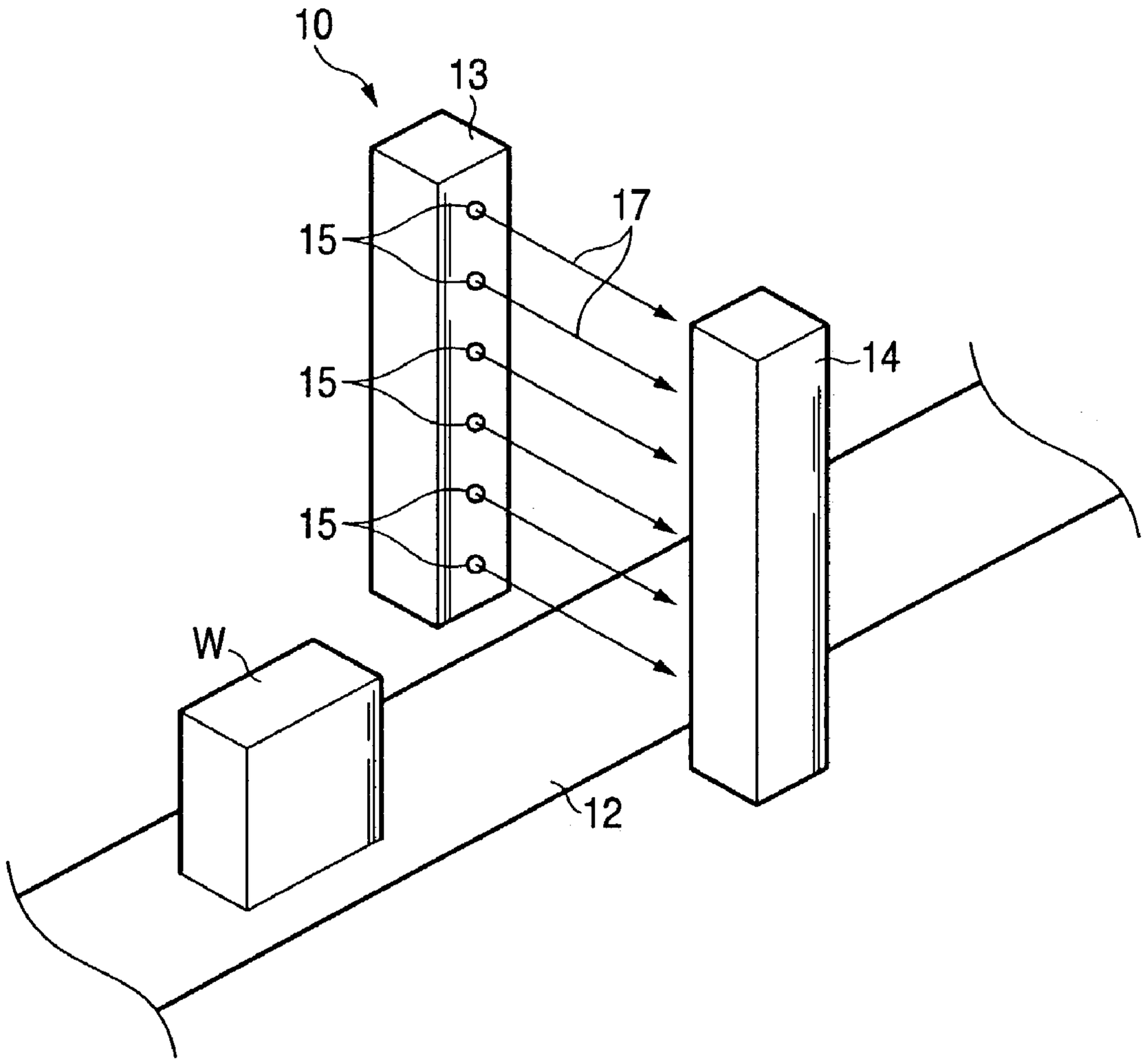


FIG. 3

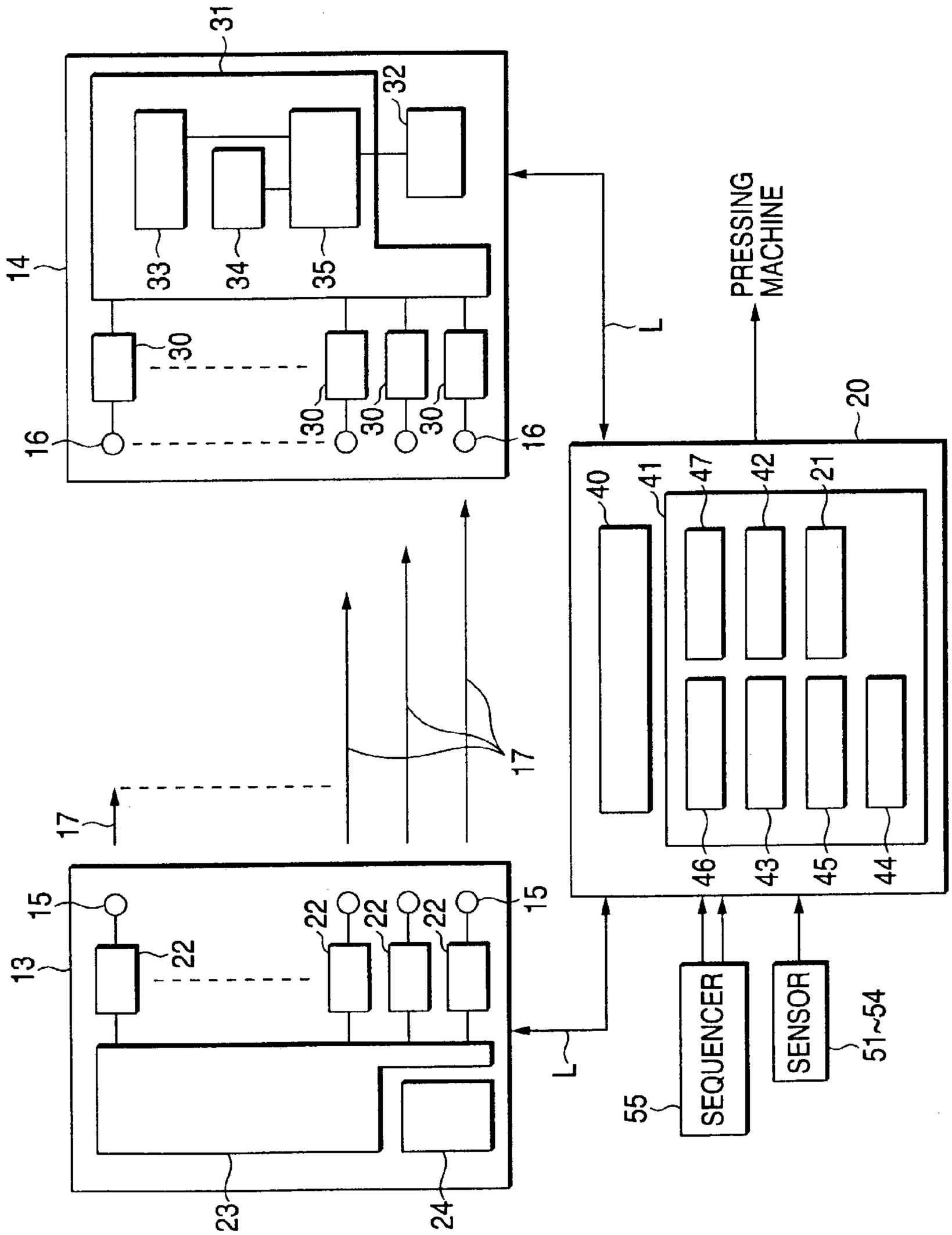

31
32
33
34
35
14
30
16
17
15
22
13
23
24
L
PRESSING MACHINE
20
40
41
47
42
21
46
43
45
44
SEQUENCER
SENSOR
55
51~54

FIG. 4

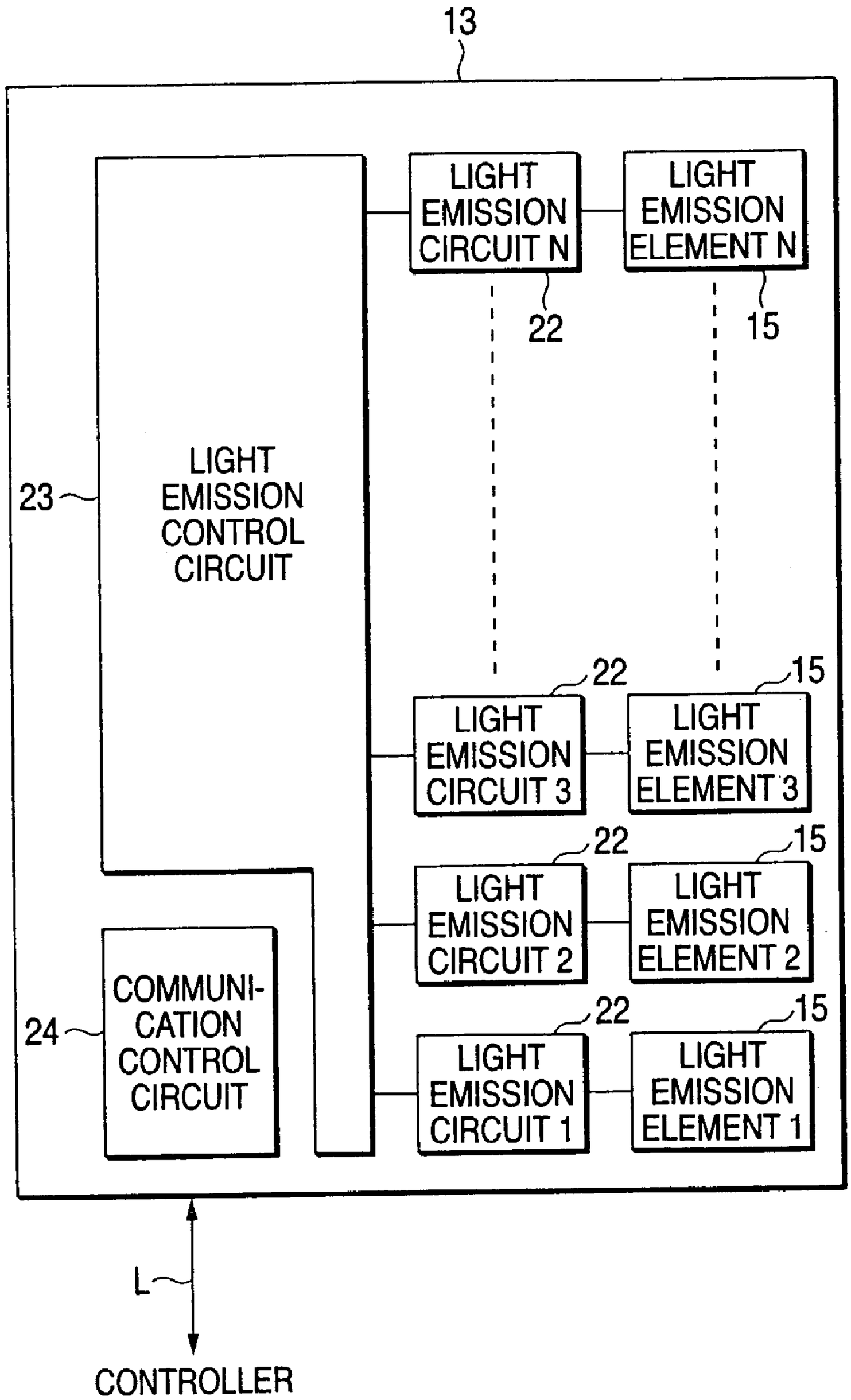

13
LIGHT EMISSION CIRCUIT N
LIGHT EMISSION ELEMENT N
22
15
23
LIGHT EMISSION CONTROL CIRCUIT
22
15
LIGHT EMISSION CIRCUIT 3
LIGHT EMISSION ELEMENT 3
22
15
LIGHT EMISSION CIRCUIT 2
LIGHT EMISSION ELEMENT 2
22
15
LIGHT EMISSION CIRCUIT 1
LIGHT EMISSION ELEMENT 1
24
COMMUNI-CATION CONTROL CIRCUIT
L
CONTROLLER

FIG. 5

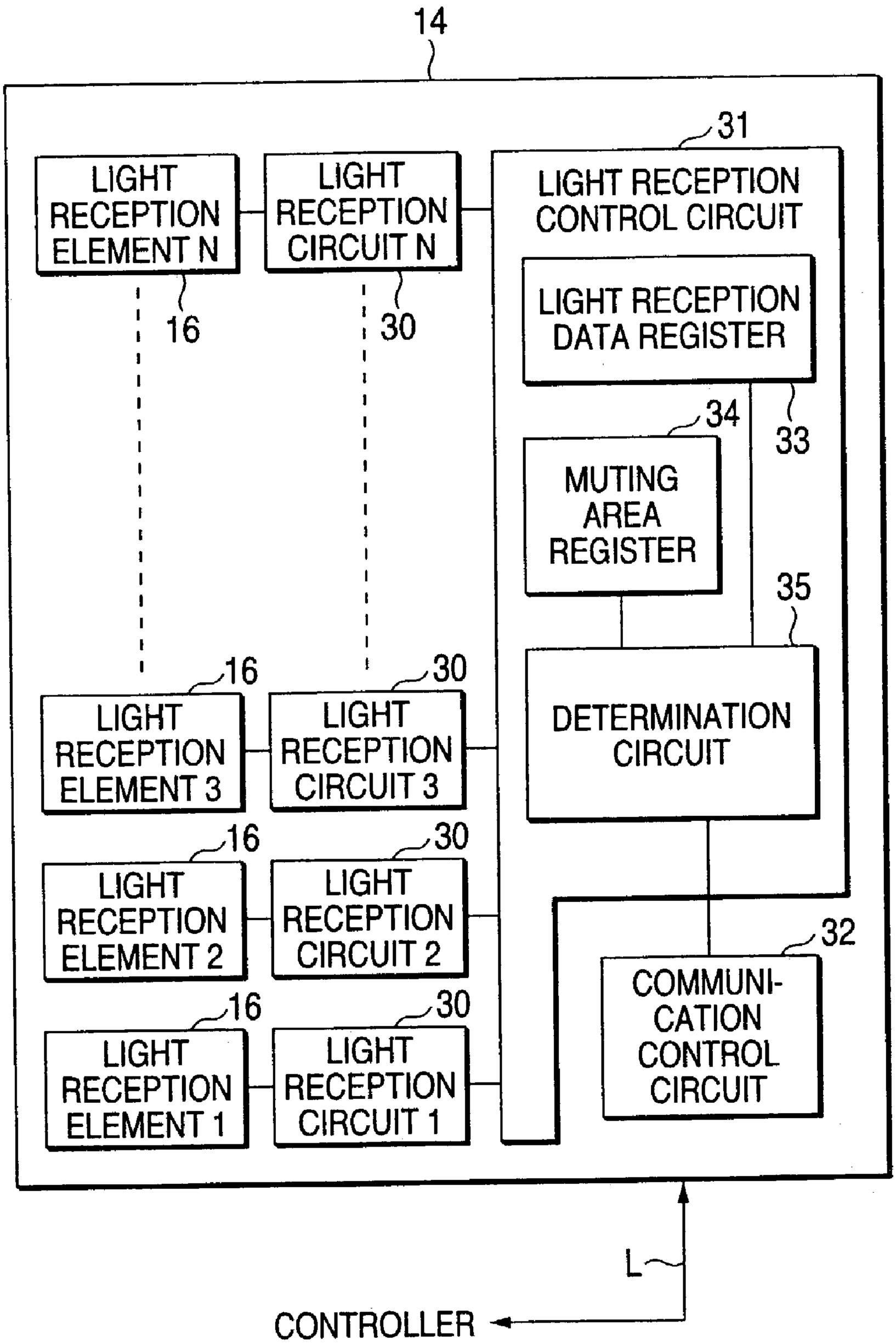

14
31
LIGHT RECEPTION ELEMENT N
LIGHT RECEPTION CIRCUIT N
LIGHT RECEPTION CONTROL CIRCUIT
LIGHT RECEPTION DATA REGISTER
16
30
34
33
MUTING AREA REGISTER
35
16
30
LIGHT RECEPTION ELEMENT 3
LIGHT RECEPTION CIRCUIT 3
DETERMINATION CIRCUIT
16
30
LIGHT RECEPTION ELEMENT 2
LIGHT RECEPTION CIRCUIT 2
32
16
30
LIGHT RECEPTION ELEMENT 1
LIGHT RECEPTION CIRCUIT 1
COMMUNI-CATION CONTROL CIRCUIT
L
CONTROLLER

FIG. 6

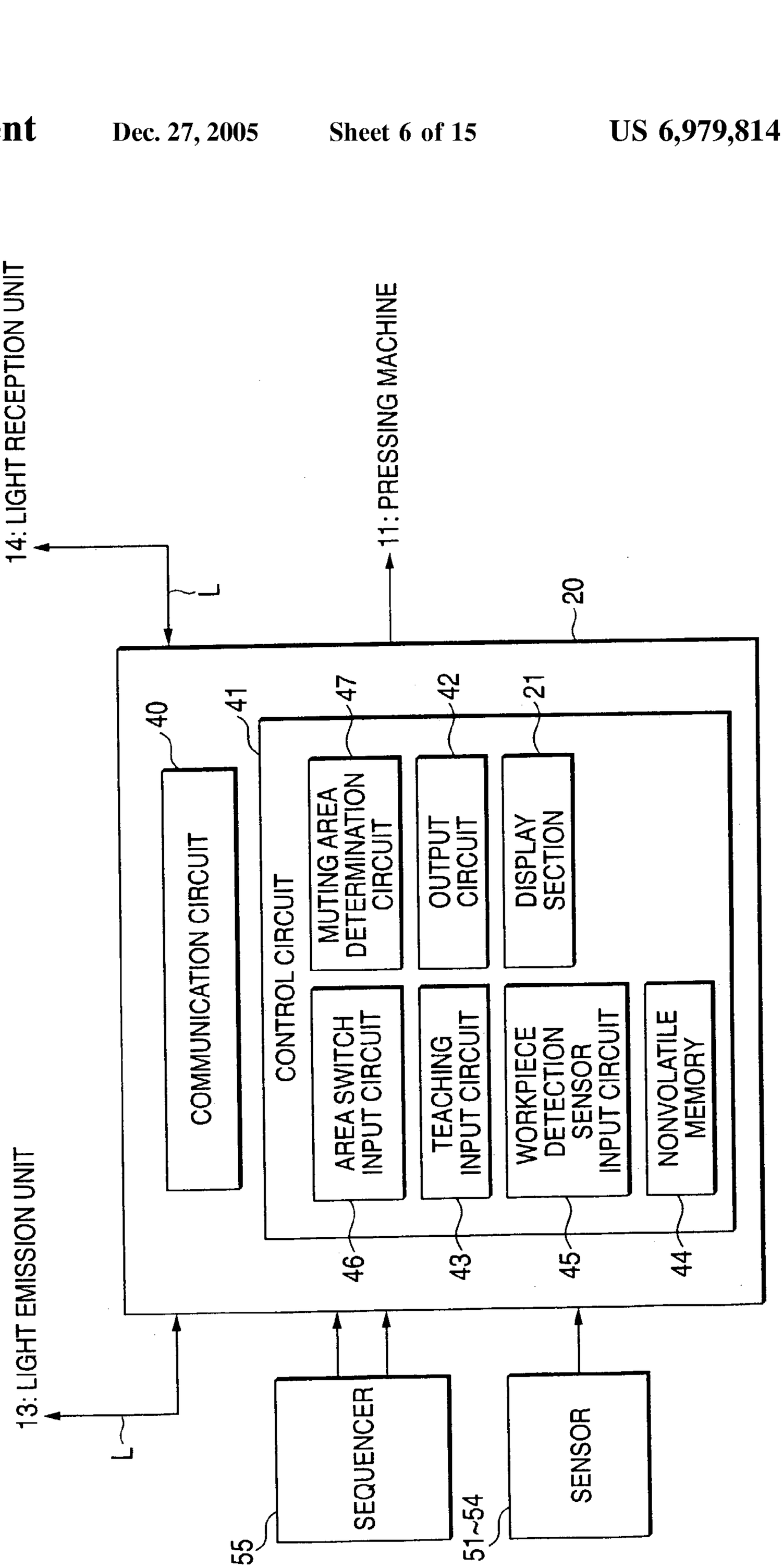

13: LIGHT EMISSION UNIT
14: LIGHT RECEPTION UNIT
1: PRESSING MACHINE
L
L
20
40
41
47
42
21
COMMUNICATION CIRCUIT
CONTROL CIRCUIT
MUTING AREA DETERMINATION CIRCUIT
OUTPUT CIRCUIT
DISPLAY SECTION
AREA SWITCH INPUT CIRCUIT
TEACHING INPUT CIRCUIT
WORKPIECE DETECTION SENSOR INPUT CIRCUIT
NONVOLATILE MEMORY
46
43
45
44
SEQUENCER
SENSOR
55
51~54

FIG. 7

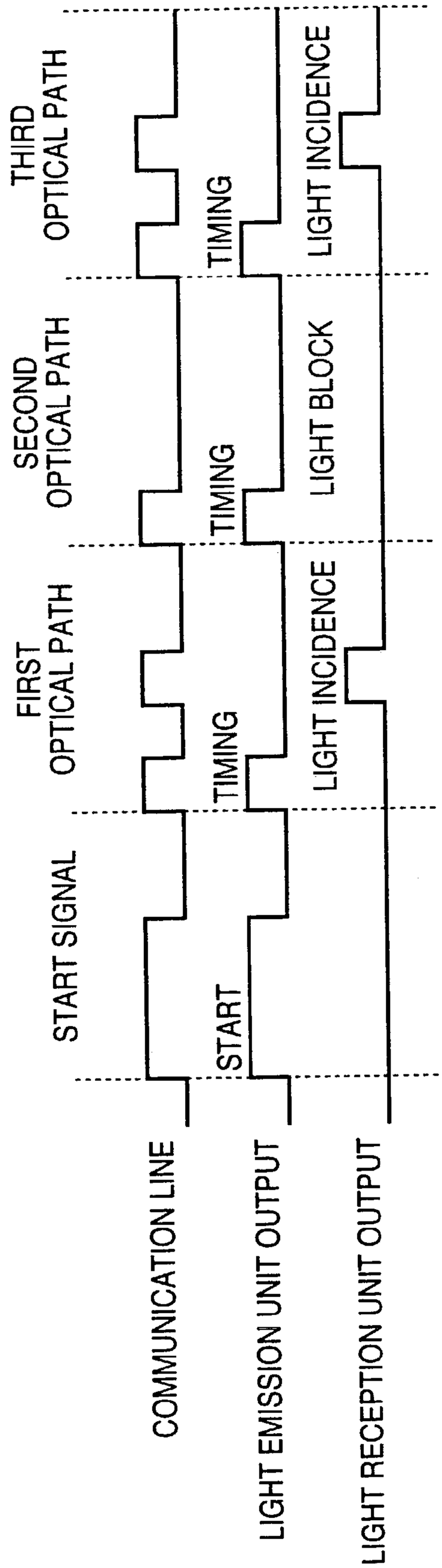

THIRD OPTICAL PATH
TIMING
LIGHT INCIDENCE
SECOND OPTICAL PATH
TIMING
LIGHT BLOCK
FIRST OPTICAL PATH
TIMING
LIGHT INCIDENCE
START SIGNAL
START
LIGHT BLOCK
COMMUNICATION LINE
LIGHT EMISSION UNIT OUTPUT
LIGHT RECEPTION UNIT OUTPUT

FIG. 8

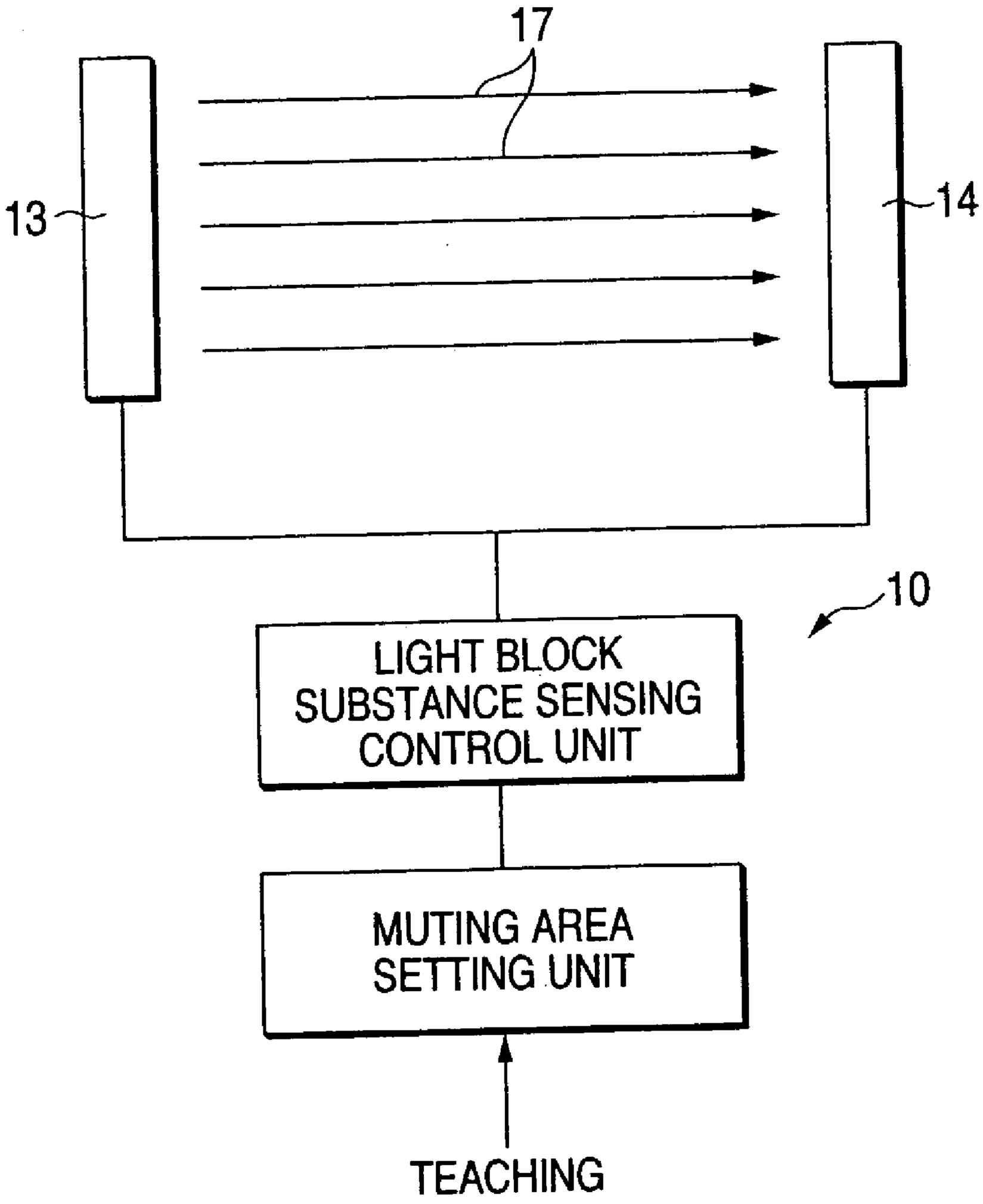

17
13
14
10
LIGHT BLOCK SUBSTANCE SENSING CONTROL UNIT
MUTING AREA SETTING UNIT
TEACHING

FIG. 9

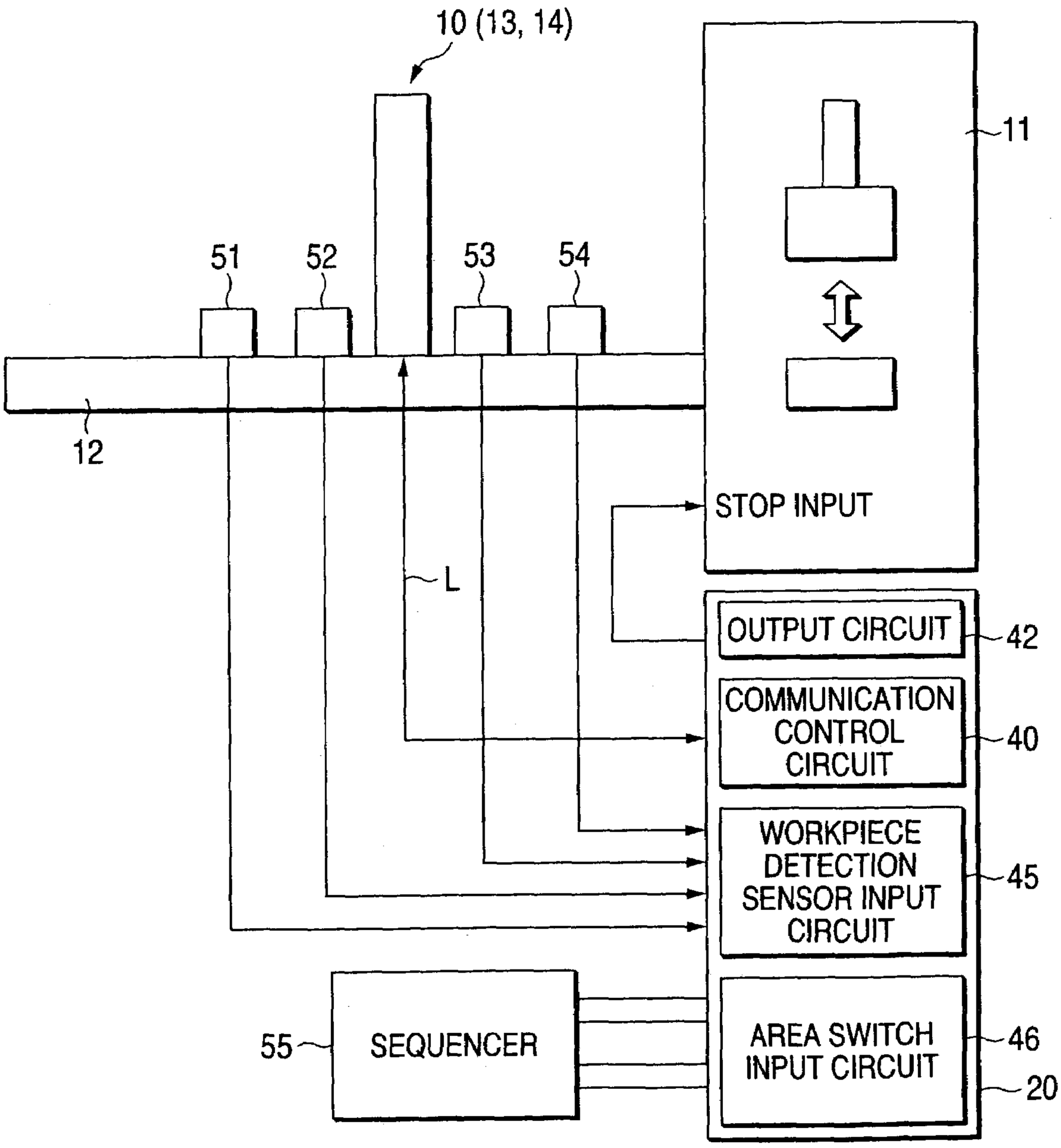

10 (13, 14)
11
51
52
53
54
12
L
STOP INPUT
OUTPUT CIRCUIT
42
COMMUNICATION CONTROL CIRCUIT
40
WORKPIECE DETECTION SENSOR INPUT CIRCUIT
45
55
SEQUENCER
AREA SWITCH INPUT CIRCUIT
46
20

FIG. 10

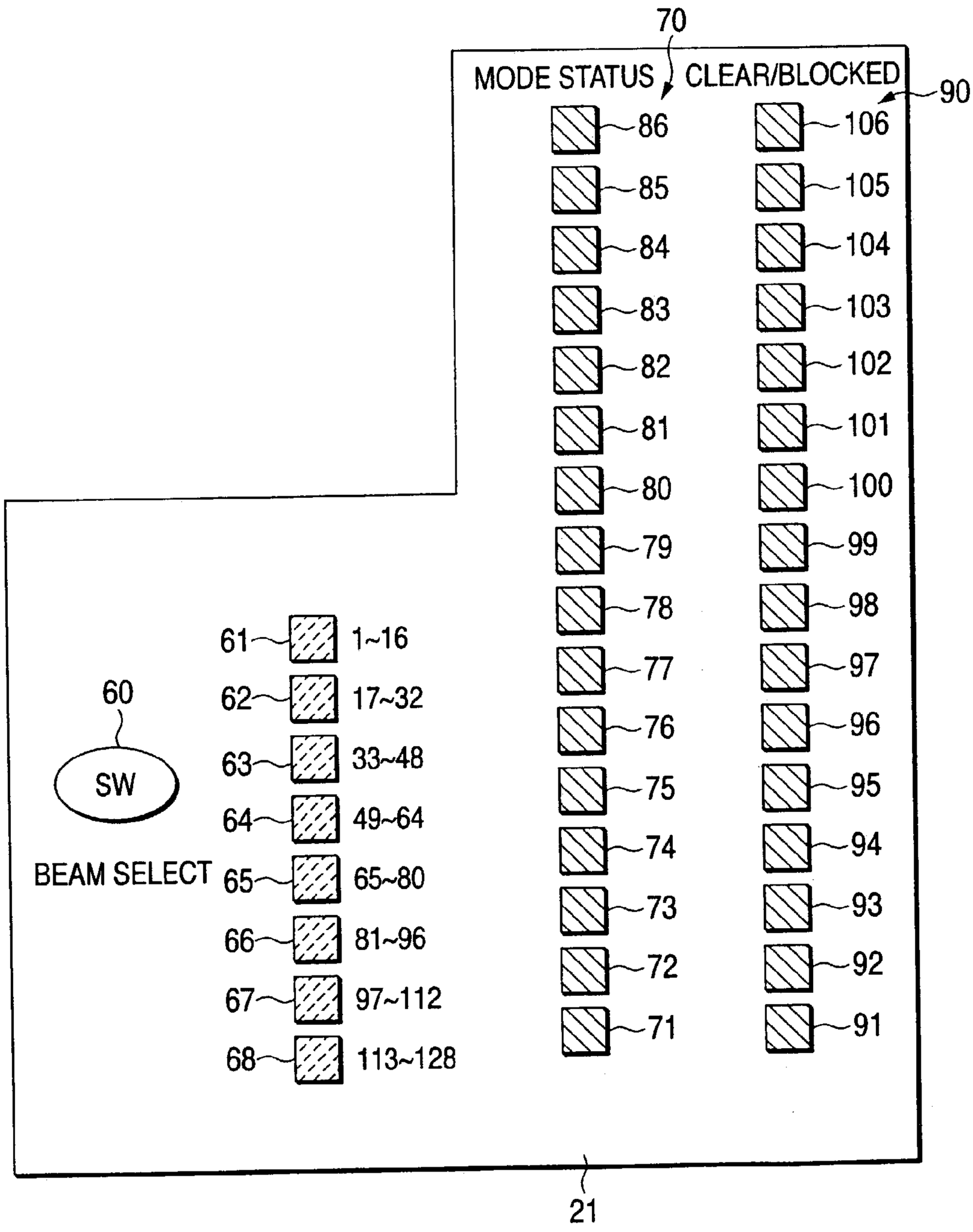

70
MODE STATUS
CLEAR/BLOCKED
90
86
85
84
83
82
81
80
79
78
77
76
75
74
73
72
71
106
105
104
103
102
101
100
99
98
97
96
95
94
93
92
91
60
SW
BEAM SELECT
61
1~16
62
17~32
63
33~48
64
49~64
65
65~80
66
81~96
67
97~112
68
113~128
21

FIG. 11

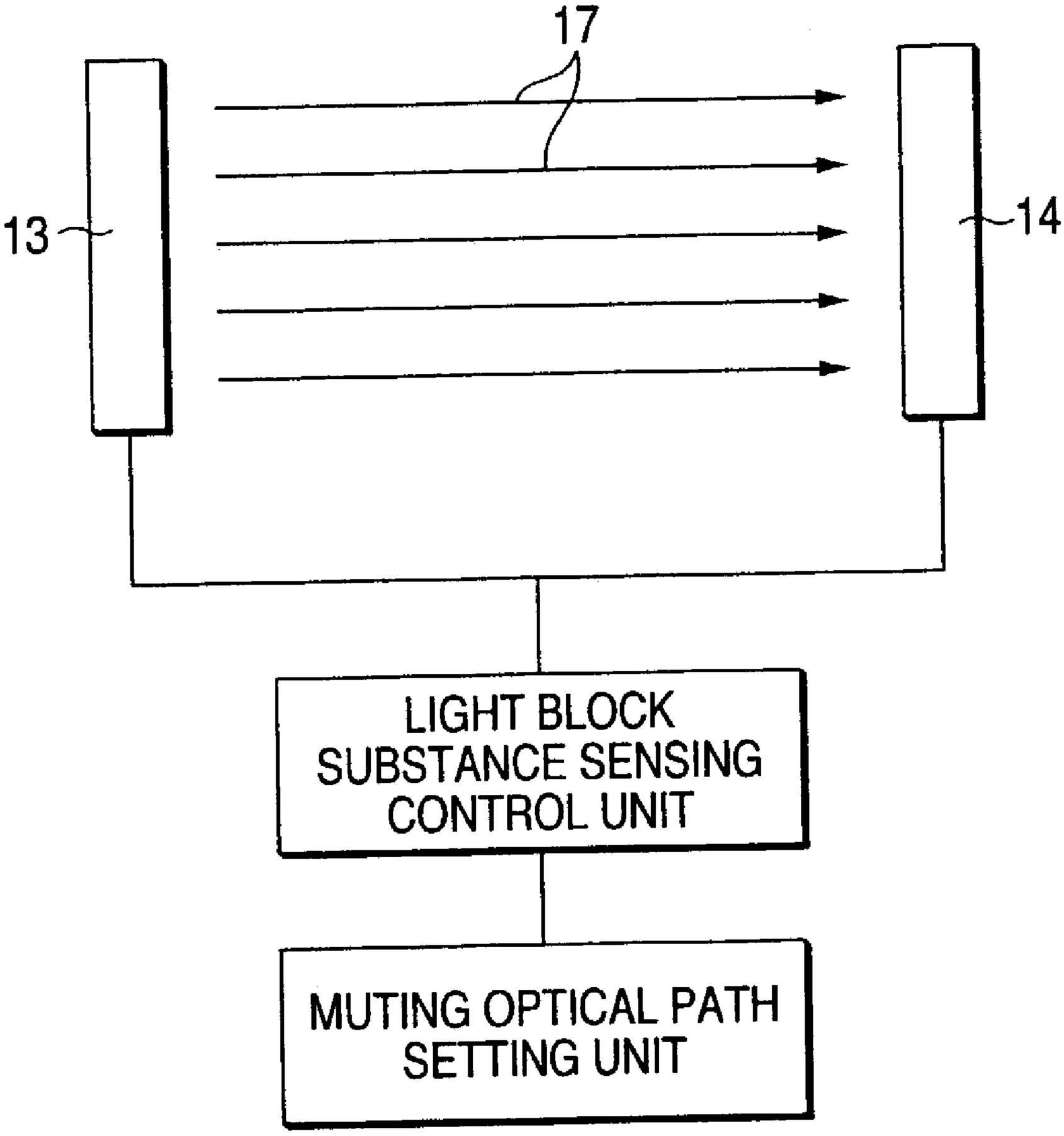

17
13
14
LIGHT BLOCK SUBSTANCE SENSING CONTROL UNIT
MUTING OPTICAL PATH SETTING UNIT

FIG. 12A

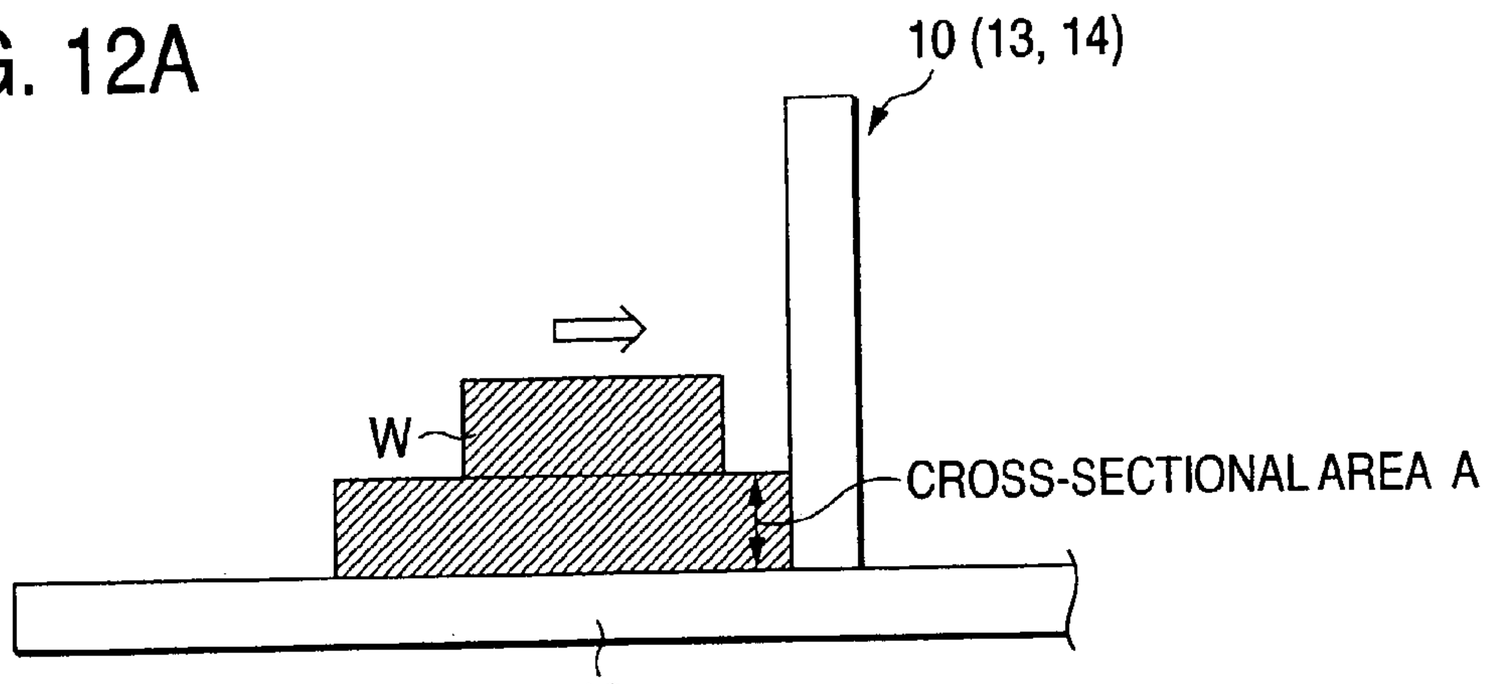


FIG. 12B

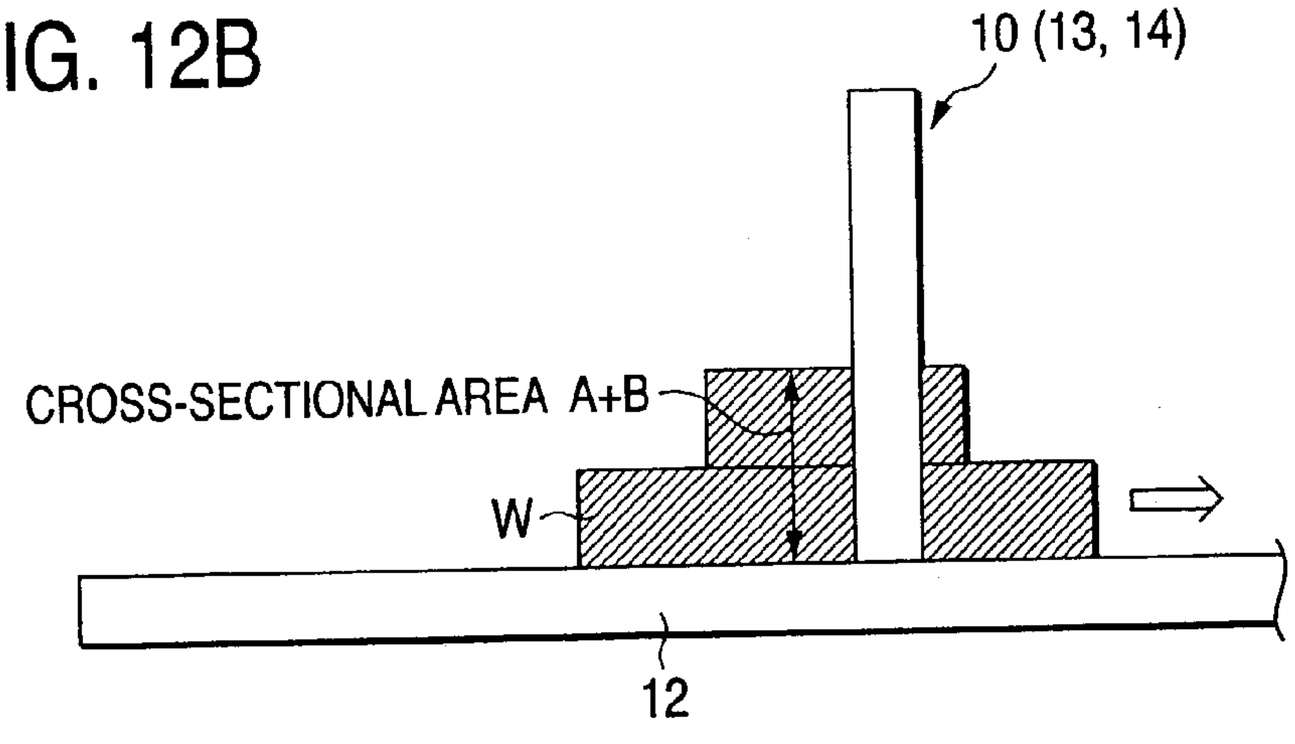


FIG. 12C

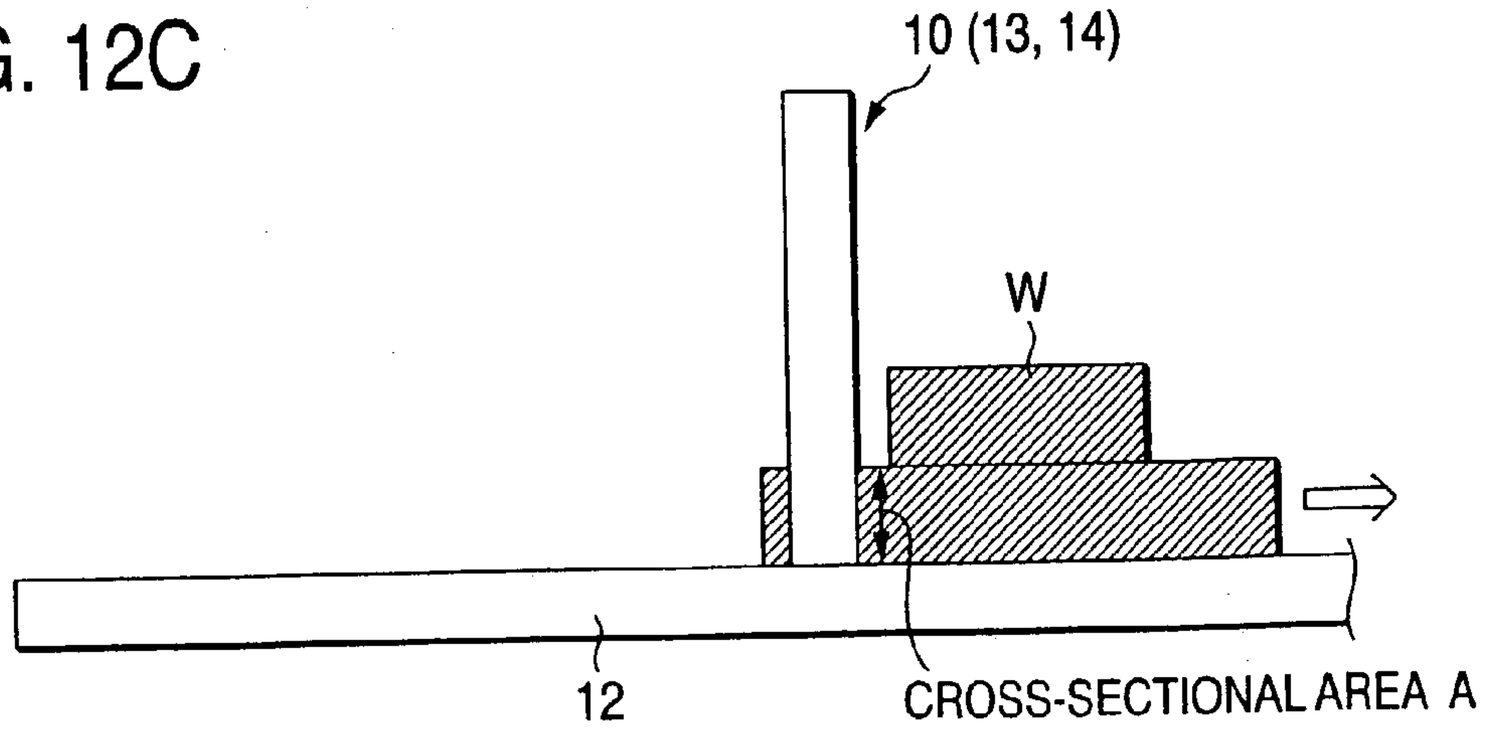


FIG. 13

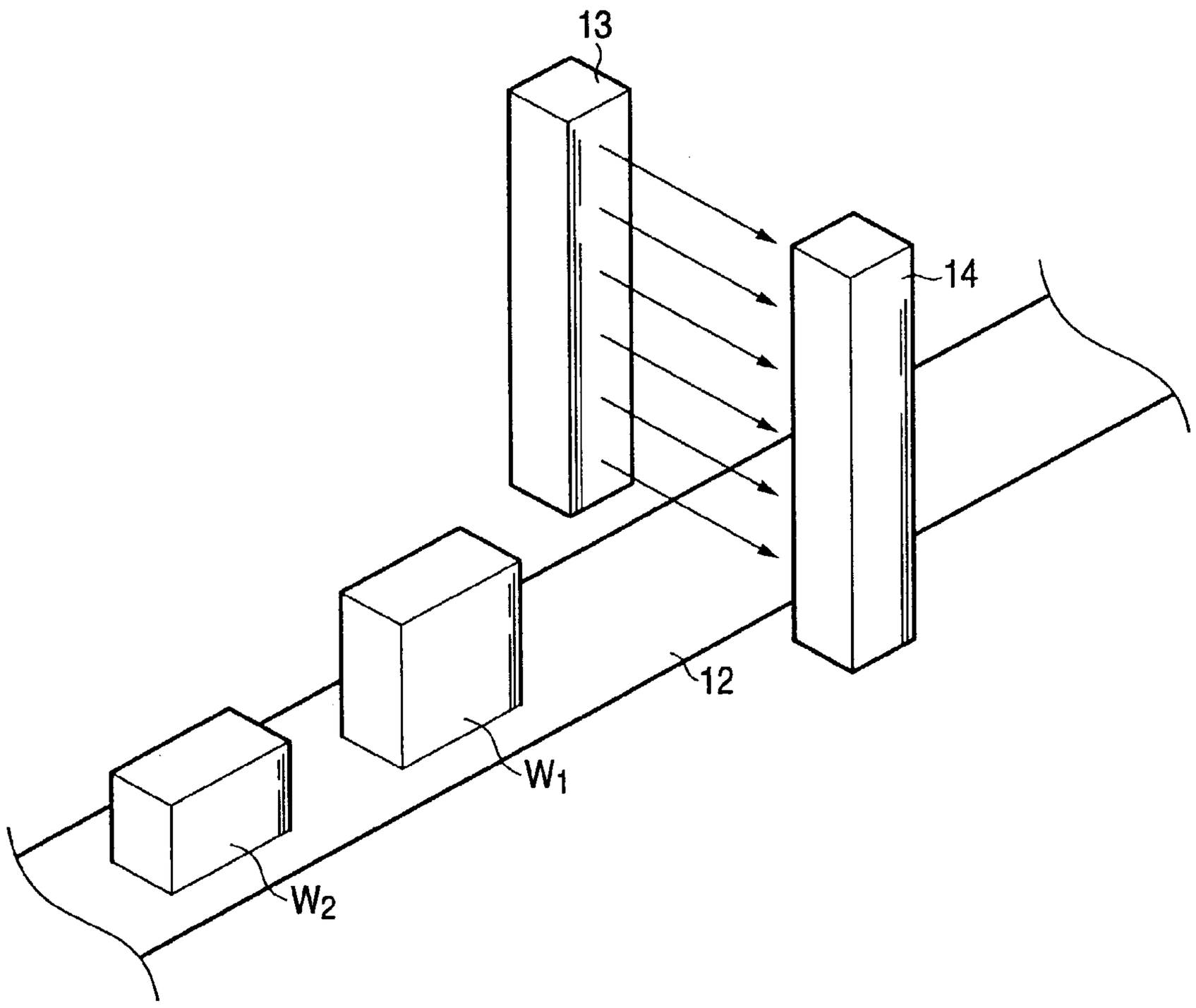


FIG. 14

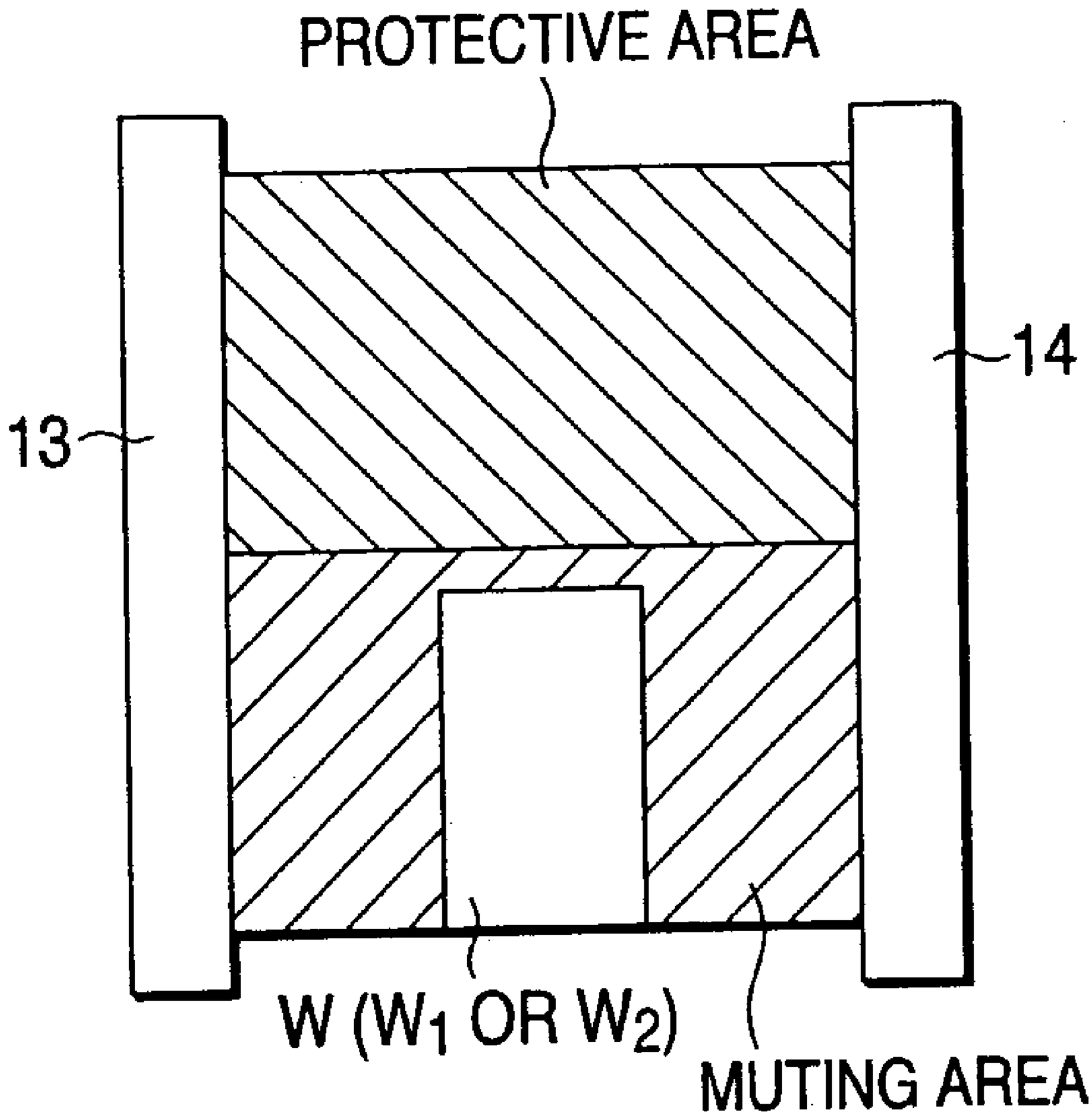
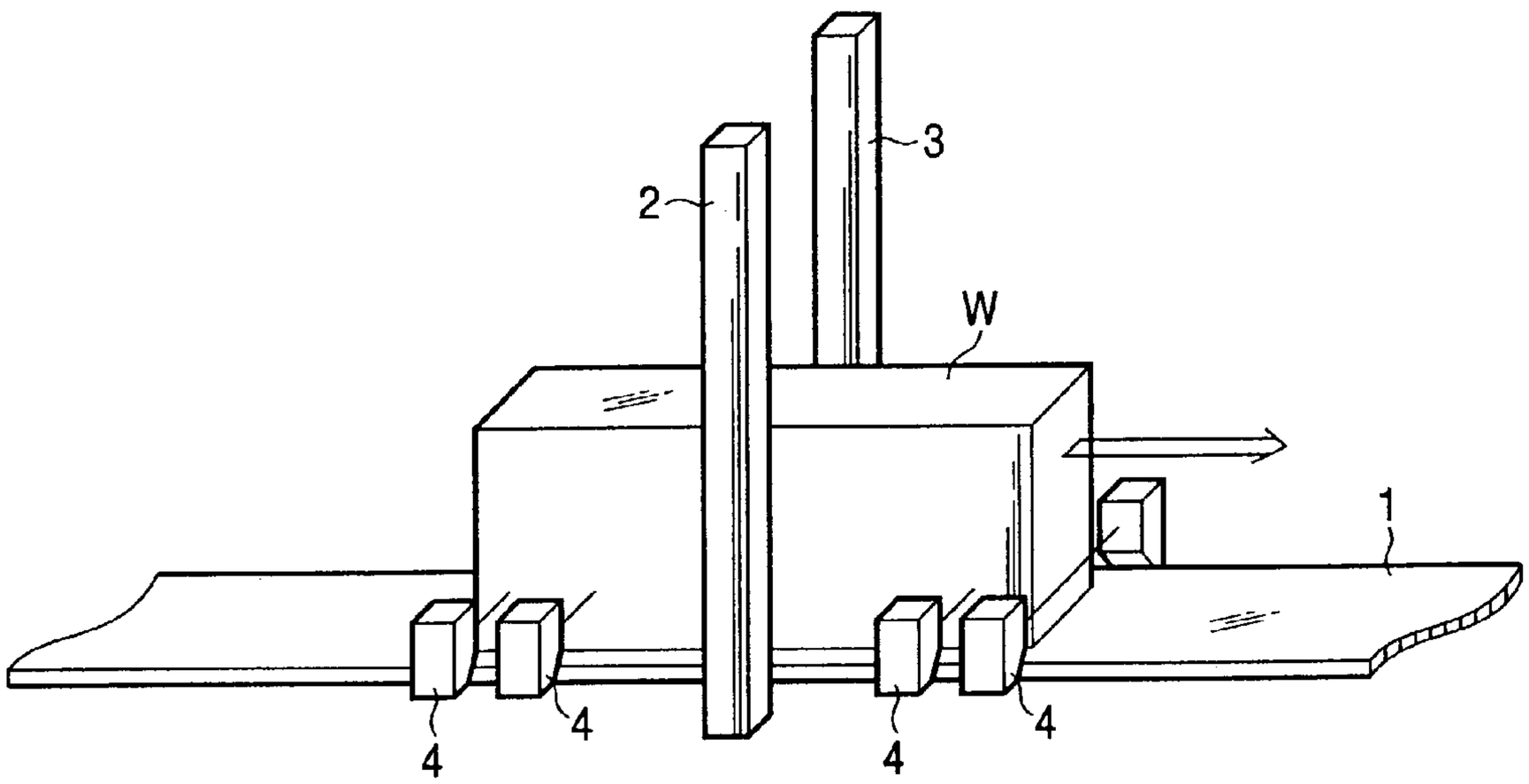


FIG. 15



MULTI-OPTICAL-PATH PHOTOELECTRIC SAFETY APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a multi-optical-path photoelectric safety apparatus having a light emitting unit and a light receiving unit. More particularly, the present invention relates to a multi-optical-path photoelectric safety apparatus comprising a muting function.

2. Discussion of the Related Art

A multi-optical-path photoelectric safety apparatus is provided to ensure worker safety when using an apparatus involving a source of danger, such as a pressing machine. The multi-optical-path photoelectric safety apparatus comprises a light emitting unit and a light receiving unit. The light emitting unit comprises a large number of light emitting elements arranged in a row. The light receiving unit comprises a corresponding number of light receiving elements as the number of the light emitting elements, and they are also arranged in a row. The light emitting and receiving units form a protective barrier by making a light curtain. When a light blocking substance through which light cannot transmit enters a detection area of the protective barrier, the operation of the machine is forcibly stopped.

In a pressing or other machine it is necessary to carry a workpiece in and carry the post-worked workpiece out. Thus, the workpiece needs to be passed through the light curtain. The multi-optical-path photoelectric safety apparatus comprises a muting function to allow the workpiece to pass through the light curtain. That is, the muting function temporarily makes the protection function of the multi-optical-path photoelectric safety apparatus ineffective when the workpiece passes through the light curtain.

FIG. **15** shows an outline of a multi-optical-path photoelectric safety apparatus comprising a muting function in a related art device. In the related art example, a light emitting unit **2** and a light receiving unit **3** are installed on either side of a conveyor line **1** carrying a workpiece into a pressing machine.

The conveyor line **1** is provided with workpiece detection sensors **4** for detecting a workpiece W passing through a light curtain. When the workpiece W is detected, the muting function is started. During the muting function in the related art device, all of the detection areas of the light curtain formed between the light emitting unit **2** and the light receiving unit **3** become ineffective.

The muting function removes the essential protection function from the multi-optical-path photoelectric safety apparatus although this protection function is only removed temporarily. However, removing the protection function of all of the detection areas of the light curtain when the muting function is operated is not preferred.

SUMMARY OF THE INVENTION

It is therefore an object of the invention to provide a multi-optical-path photoelectric safety apparatus for making a muting function effective while exerting the essential protection function of the multi-optical-path photoelectric safety apparatus. Namely, a light block substance sensing function provides compatibility between the functions, thereby making it possible to allow a light block substance, such as a workpiece, to pass through a light curtain while continuing to ensure safety.

To this end, according to the invention, there is provided a multi-optical-path photoelectric safety apparatus comprising: a light emitting unit; a light receiving unit forming a light curtain with the light receiving unit; and a muting function for temporarily rendering a protection function of the light curtain ineffective by allowing a predetermined light block substance to pass through the light curtain, and wherein the muting function includes defining a muting area where the muting function is performed and the muting areas is in a region of a detection area forming the light curtain.

Preferably, the muting area can be taught to be set to a size related to a predetermined light block substance.

According to the invention, the muting function serves substantially only the area through which a predetermined light block substance passes in the light curtain formed between the light emitting unit and the light receiving unit. In the other areas, the essential protection function of the multi-optical-path photoelectric safety apparatus is on continuously. Therefore, compatibility between the essential protection function of the multi-optical-path photoelectric safety apparatus and the muting function can be provided. This allows a light block substance such as a workpiece to pass through the light curtain while safety is maintained.

These and other objects and advantages of the invention will become more apparent from the detailed description of the preferred embodiments described below.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a drawing to describe an outline of a multi-optical-path photoelectric safety apparatus installed in a conveyor line according to an embodiment of the present invention.

FIG. **2** is a drawing describing a placement example of a light emitting unit and a light receiving unit included in the multi-optical-path photoelectric safety apparatus according to an embodiment of the present invention.

FIG. **3** is a block diagram showing a general configuration of the multi-optical-path photoelectric safety apparatus according to an embodiment of the present invention.

FIG. **4** is an enlarged block diagram of the light emitting unit in the multi-optical-path photoelectric safety apparatus according to an embodiment of the present invention.

FIG. **5** is an enlarged block diagram of the light receiving unit included in the multi-optical-path photoelectric safety apparatus according to an embodiment of the present invention.

FIG. **6** is an enlarged block diagram of a controller included in the multi-optical-path photoelectric safety apparatus according to an embodiment of the present invention.

FIG. **7** is a chart describing the contents of the signals passing through a communication line or a signal line for connecting the light emitting unit, the light receiving unit, and the controller in the multi-optical-path photoelectric safety apparatus according to an embodiment of the present invention.

FIG. **8** is a block diagram conceptually showing a means for setting a muting area by teaching with a limited partial area in a light curtain.

FIG. **9** is a diagram to show a general configuration of the multi-optical-path photoelectric safety apparatus according to an embodiment of the present invention.

FIG. **10** is a drawing describing an outline for a display section installed in the controller.

FIG. **11** is a block diagram conceptually showing a means for setting a muting area as a limited partial area in a light curtain by a user who manually enters the muting area from the outside.

FIGS. **12**A–**12**C are drawings describing the switching to a muting area having a size responsive to the cross-sectional area of a workpiece when the workpiece contains portions having different heights that pass through the light curtain.

FIG. **13** is a drawing describing the switching to a muting area responsive to the size of a workpiece when different types of workpieces are transported on the conveyor line.

FIG. **14** is a drawing describing a muting area of a size corresponding to the size of a workpiece.

FIG. **15** is a drawing describing a muting function of a multi-optical-path photoelectric safety apparatus in a related art device.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A multi-optical-path photoelectric safety apparatus **10** according to a first embodiment includes a light emitting unit **13** and a light receiving unit **14** placed on either side of a conveyor line **12** that extends to a pressing machine **11** as shown in FIGS. **1** and **2**.

As seen in FIG. **2**, the light emitting unit **13** has an elongated case extending in a longitudinal direction and comprises N light emitting elements **15** (that are particularly shown in FIG. **3**). The light emitting elements **15** are placed in the case at equal intervals in a row along the lengthwise direction of the case. The interval between the adjacent light emitting elements **15** is not specifically limited and can be, for example, 20 mm.

Likewise, the light receiving unit **14** has an elongated case extending in a longitudinal direction and comprises a corresponding number of light receiving elements **16** (FIG. **3**) as the number of the light emitting elements **15**. The light receiving elements **16** are placed in the case at equal intervals in a row along the lengthwise direction of the case. The interval between the adjacent light receiving elements **16** is the same as the interval that is used between the adjacent light emitting elements **15**.

The light emitting unit **13** and the light receiving unit **14** are placed facing each other with the conveyor line **12** being disposed there between. A horizontal light beam is emitted from each light emitting element **15** of the light emitting unit **13** to the light receiving element **16** of the light receiving unit **14** that corresponds to the light emitting element **15**. This forms a light curtain crossing the conveyor line **12** and provides a protective barrier, as shown in FIG. **2**. Reference numeral **17** in FIG. **2** denotes an optical path or a light beam and substantially represents a part of the light curtain.

The multi-optical-path photoelectric safety apparatus **10** has a controller **20** as shown in FIG. **3**. The controller **20** preferably includes a state display monitor or user interface display section **21**.

FIGS. **3** to **6** are block diagrams relevant to the multi-optical-path photoelectric safety apparatus **10**. FIG. **3** is a block diagram to show the general configuration of the multi-optical-path photoelectric safety apparatus **10**. FIG. **4** is a block diagram of the light emitting unit **13**. FIG. **5** is a block diagram of the light receiving unit **14**. Further, FIG. **6** is a block diagram of the controller **20**.

Referring particularly to FIG. **4**, the light emitting element **13** comprises the N light emitting elements **15**, N light emitting circuits **22**, a light emitting control circuit **23**, and a communication control circuit **24**. The light emitting

circuits **22** are provided in a one-to-one correspondence with the light emitting elements **15** which can be, for example, light emitting diodes for driving them. The light emitting control circuit **23** controls the light emitting circuits **22**. The communication control circuit **24** controls communications with the controller **20**. Upon receiving an instruction from the controller **20**, the light emitting control circuit **23** starts the N light emitting circuits **22** in order. This sequentially turns on the light emitting element **15** of the first optical path to the light emitting element **15** of the Nth optical path. Accordingly, the light emitting element **13** emits a light beam in order from the first optical path through the Nth optical path to the light receiving unit **14** at predetermined light emitting timings.

Referring to FIG. **5**, the light receiving element **14** comprises the N light receiving elements **16**, N light receiving circuits **30**, a light receiving control circuit **31**, and a communication control circuit **32**. The light receiving circuits **30** are provided in a one-to-one correspondence with the light receiving elements **16**. The light receiving control circuit **31** controls the light receiving circuits **30**. The communication control circuit **32** controls communications with the controller **20**. Upon receiving a control signal from the controller **20**, the light receiving control circuit **31** makes the light receiving circuit **30** of the first optical path to the light receiving circuit **30** of the Nth optical path operate in synchronization with the operation of the corresponding light emitting circuits **22**. This allows the light beams emitted one after another from the light emitting unit **13** to be received at the corresponding light receiving elements **16**.

The light receiving control circuit **31** also preferably includes a light receiving data register **33**, two muting area registers **34**, and a determination circuit **35**. The light receiving data register **33** temporarily stores the light receiving data. The muting area register **34** stores information concerning a muting area as will be described later. The determination circuit **35** determines whether any one of optical paths in a detection area other than the muting area is in a light block state based on light incidence/light block information in the detection area outside the muting area (when the muting operation is performed). The determination circuit **35** determines whether any one of the optical paths is in a light blocked state based on the light incidence/light block information in all of the areas of the light curtain when no muting operation is performed.

Referring to FIG. **6**, the controller **20** comprises a communication circuit **40** for conducting communications between the light emitting unit **13**, the light receiving unit **14** and a control circuit **41**.

The light emitting unit **13**, the light receiving unit **14**, and the controller **20** are connected by the communication line or the signal line L. This line L allows not only communications, but also transfer of the light incidence/light block information (FIG. **7**) between the controller **20**, the light emitting unit **13** and the light receiving unit **14**. As seen in FIG. **7**, a signal on the communication line or the signal line L is provided by combining the timing signal output from the light emitting unit **13** and the light incidence/light block information signal output from the light receiving unit **14**.

The control circuit **41** of the controller **20** preferably comprises the state display monitor or user interface display section **21**. The control circuit **41** also comprises an output circuit **42** for turning on/off an output signal for an operation stop signal, etc., to the pressing machine **11** based on information from the determination circuit **35** of the light receiving unit **14**.

The controller **20** comprises a teaching input circuit **43** for the user to set a muting area by teaching. The teaching input circuit **43** has a teaching button (not shown) forming a part of input means that can be operated manually by the user. By operating this button, the user can switch the mode between a teaching mode where the user sets a muting area by a teaching method and a normal operation mode (RUN mode) where the multi-optical-path photoelectric safety apparatus **10** operates its essential functions.

The control circuit **41** of the controller **20** further comprises at least one nonvolatile memory **44**. When the mode is switched from the teaching mode to the normal operation mode by the user operating the teaching button, the muting area set in the teaching mode is stored in the nonvolatile memory **44**.

Means related to setting the muting area by the teaching method described above is shown in FIG. **8**. That is, the multi-optical-path photoelectric safety apparatus **10** has the light emitting unit **13**, the light receiving unit **14**, a control unit, and a muting area setting unit. The light emitting unit **13** preferably comprises a large number of light emitting elements equally spaced from each other and that are placed in a row. The light receiving unit **14** is placed facing the light emitting unit **13**. The light receiving unit comprises as many light receiving elements as the number of the light emitting elements. The light receiving elements are equally spaced from each other and they are also placed in a row. For each optical path **17**, the control unit controls a light blocking substance sensing function for the multi-optical-path light curtain that senses the entry of a light blocking substance between the light emitting unit **13** and the light receiving unit **14**. The muting area setting unit sets a muting area by a teaching mode. It also operates the muting function to temporarily make the light blocking substance sensing function ineffective as a predetermined light blocking substance (such as a workpiece) is allowed to pass through the light curtain. The muting area setting unit enables the user to set the muting area to operate in a limited area of the light curtain.

In FIG. **9**, a plurality of workpiece detection sensors **51** to **54** are disposed on the conveyor line **12**. The light emitting unit **13** and the light receiving unit **14** are between these sensors in the workpiece transport direction. The signals from the sensors **51** to **54** are input to a workpiece detection sensor input circuit **45** of the controller **20**.

The conveyor line **12** and the pressing machine **11** are controlled integrally by a sequencer **55**. If more than one muting area is set, a muting area switch signal is sent from the sequencer **55** to an area switch input circuit **46** of the controller **20** as shown in FIGS. **6** and **9**.

FIG. **10** shows an example of the state display monitor or user interface display section **21**. The display section **21** comprises an optical path area selection switch **60** and has a plurality of LED indicator lamps **61** to **68** that are slightly spaced apart and placed in a row in the longitudinal direction to the right of the selection switch **60**.

The display section **21** also has a mode state indicator lamp group **70** made up of a plurality of LEDs. The mode state indicator lamp group **70** is not limited to a particular number of lamps. In the embodiment shown, the mode state indicator lamp group **70** is preferably made up of 16 LED indicator lamps **71** to **86** as the basic unit having 16 optical paths. These lamps are slightly spaced apart and are placed with in a row in the longitudinal direction.

The display section **21** also has a light incidence/light block state indicator lamp group **90** made up of a plurality of LEDs. The light incidence/light block state indicator lamp group **90** is not limited to a particular number of lamps. In the embodiment shown, the light incidence/light block state indicator lamp group **90** is preferably made up of 16 LED indicator lamps **91** to **106** as the basic unit having 16 optical paths. These lamps are also slightly spaced apart and are placed in a row in the longitudinal direction.

Since the light incidence/light block information is always supplied from the light receiving unit **14** to the controller **20** over the communication line or the signal line L during the operation of the controller **20**, the display section **21** of the controller **20** is updated in real time.

The optical path area selection switch **60** assumes that the light emitting unit **13** and the light receiving unit **14** comprise a maximum of 128 optical paths. Also, the optical path area selection switch **60** provides a selection means for allowing the user to select the optical path area to be displayed on the display section **21** so as to display, in 16 optical-path units, information concerning all of the optical paths on the mode state indicator lamp group **70** and the light incidence/light block state indicator lamp group **90**. When the light emitting unit **13** and the light receiving unit **14** comprise 64 optical paths and the user operates the optical path area selection switch **60** to selecting the first block (consisting of the first optical path to the sixteenth optical path), the mode state and the light incidence/light block state of each of these paths are displayed on the mode state indicator lamp group **70** and the light incidence/light block state indicator lamp group **90**.

Next, if the user presses the optical path area selection switch **60** again and selects the second block (consisting of the seventeenth optical path to the thirty-second optical path), the mode state and the light incidence/light block state of each of these paths are displayed on the mode state indicator lamp group **70** and the light incidence/light block state indicator lamp group **90**. If the user presses the optical path area selection switch **60** again and selects the third block (consisting of the thirty-third optical path to the forty-eighth optical path), the mode state and the light incidence/light block state of each of these paths are displayed on the mode state indicator lamp group **70** and the light incidence/light block state indicator lamp group **90**.

If the user again presses the optical path area selection switch **60** and selects the fourth block (consisting of the forty-ninth optical path to the sixty-fourth optical path), the mode state and the light incidence/light block state of each of these paths are displayed on the mode state indicator lamp group **70** and the light incidence/light block state indicator lamp group **90**.

It is preferred that the basic unit uses eight indicator lamps **61–68**, each lamp being for 16 optical paths. The lamps are disposed to the right of the switch **60** and indicate the current optical path area selected from among the eight blocks to show the first optical path to the 128th optical path. The indicator lamps **61–68** are arranged in a row in the longitudinal direction and are assigned from top to bottom as follows: The indicator lamp **61** to the first to sixteenth optical paths; the indicator lamp **62** to the seventeenth to thirty-second optical paths; the indicator lamp **63** to the thirty-third to forty-eighth optical paths; the indicator lamp **64** to the forty-ninth to sixty-fourth optical paths; the indicator lamp **65** to the sixty-fifth to eightieth optical paths; the indicator lamp **66** to the eighty-first to ninety-sixth optical paths; the indicator lamp **67** to the ninety-seventh to 112th optical paths; and the indicator lamp **68** to the 113th to 128th optical paths. To display these assignments, an identification

sign or numeral (**1–16**, **17–32**, . . . , **113–128**) is preferably added to the right or top or bottom of each of the indicator lamps **61–68**.

The optical path area indicator lamps **61–68** may also be assigned to the optical paths as desired. For example, they may be assigned in an order from bottom to top starting with the first to sixteenth optical paths, the seventeenth to thirty-second optical paths, . . . , the 113th to 128th optical paths. When the indicator lamps contained in the indicator lamp groups **70** and **90** are placed side by side, the optical path area indicator lamps **61–68** may be assigned in an order from right to left starting with the first to sixteenth optical paths, the seventeenth to thirty-second optical paths, . . . , the 113th to 128th optical paths or they may be assigned in order from left to right starting with the first to sixteenth optical paths, the seventeenth to thirty-second optical paths, . . . , the 113th to 128th optical paths.

When the muting area is set, the indicator lamps of the mode state indicator lamp group **70** that correspond to the optical paths where muting is set, are turned on. Accordingly, the user can visually check whether or not the muting area is set for each optical path.

As shown in FIG. **6**, the control circuit **41** of the controller **20** further includes a muting area determination circuit **47** for determining a muting area from the light incidence/light block information received from the light receiving unit **14** and the teaching operation information received from the teaching input circuit **43**. This muting area determination circuit **47** may include a user interface for enabling the user to directly enter a muting area by, for example, a switch input and/or by a numeric keypad.

FIG. **11** generally shows a means for setting the muting area by an external input as described above. The multi-optical-path photoelectric safety apparatus **10** has the light emitting unit **13**, the light receiving unit **14**, the control unit and the muting optical path setting unit. The light emitting unit **13** comprises a large number of light emitting elements equally spaced from each other and placed in a row. The light receiving unit **14** faces the light emitting unit **13** and comprises as many light receiving elements as the number of the light emitting elements. The light receiving elements are also equally spaced from each other and are placed in a row. For each optical path **17**, the control unit controls a light blocking substance sensing function for the multi-optical-path light curtain that senses the entry of a light blocking substance between the light emitting unit **13** and the light receiving unit **14**. Also for each optical path **17**, the muting optical path setting unit sets the muting function to temporarily make the light blocking substance sensing function of the light curtain ineffective as a predetermined light blocking substance (such as a workpiece) is allowed to pass through the light curtain. The muting optical path setting unit allows the user to set the muting area to operate in a limited area of the light curtain.

The teaching operation for storing a part of the detection area of the light curtain in the control circuit **41** as the muting area will now be discussed.

(Step 1) The user switches a switch (not shown) contained in the control circuit **41** of the controller **20** for making the muting function effective.

(Step 2) The user switches a switch (not shown) of the teaching input circuit **43** of the controller **20** for switching the mode from the normal operation mode (RUN mode) to the teaching mode for setting a first muting area.

(Step 3) The user operates the teaching button of the teaching input circuit **43**, thereby placing the apparatus in the teaching state, and the user blocks light in the area where the muting function will operate in the light curtain formed between the light emitting unit **13** and the light receiving unit **14**. Next, the user operates the teaching button again to confirm the teaching input. In other words, the optical paths blocked between the first teaching button operation and the second teaching button operation are stored as the muting area. The control circuit **31** of the light receiving unit **14** determines whether or not the light receiving circuit **30** for each optical path in the light receiving unit **14** receives the light beam from the corresponding optical path in the light emitting unit **13**. The control circuit **31** supplies the light incidence/light block information for each optical path over the communication line or the signal line L to the controller **20** for temporary storage in a register (not shown) of the muting area determination circuit **47**. The muting area determination circuit **47** determines whether or not the light incidence/light block information from the light receiving unit **14** matches the information from the teaching input circuit **43**, and then determines the muting area.

(Step 4) The user checks on the display section **21** of the controller **20** to see if the muting area is set by performing the teaching operation as intended.

(Step 5) If the user checks and determines that the muting area is set as intended, then the user switches the switch of the teaching input circuit **43** of the controller **20** to switch the mode from the teaching mode to the normal operation mode (RUN mode), and the controller **20** stores the setup first muting area in the nonvolatile memory **44**.

(Step 6) The user then executes steps 2 to 5 again to set a second muting area and to store the setup second muting area in the nonvolatile memory **44** of the controller **20**.

(Step 7) The user then executes steps 2 to 5 again to set and store a third muting area as required. This step can be repeated for setting additional muting areas.

Next, the operation of the multi-optical-path photoelectric safety apparatus **10** after one or more muting areas are set will be discussed in connection with the case where two muting areas are set. This procedure is preferably applied to a predetermined light block substance or workpiece having portions with different heights such as the workpiece W shown in FIG. **1**. It can also be applied to two or more types of predetermined light block substances or workpieces having different heights.

Referring to FIG. **9**, a muting area switching signal is input from the sequencer **55** to the area switch input circuit **46** of the controller **20**. The controller **20** determines whether or not the input signal is correct. For example, if two input lines are connected for safety, namely, a dual-redundant input signal is adopted, the controller **20** determines whether or not the input signal is correct based on whether the logic of one signal matches that of the other signal.

If it is determined that the input signal is correct, the muting area is switched in accordance with the input signal. For example, the information concerning the first muting area stored in the nonvolatile memory **44** of the controller **20** is transferred to the muting area register **34** of the light receiving unit **14**.

When the information is transferred to the light receiving unit **14** it is important to avoid the risk of malfunction in the register and to avoid the risk of malfunction caused by noise when the muting area information is transferred from the controller **20** to the light receiving unit **14**. In this regard, a dual-redundant muting area register is preferably adopted and when the data is transferred, verification is also conducted.

Only when a predetermined light block substance or workpiece W transported on the belt conveyor **12** is detected by the workpiece detection sensor **51**, **52** and a detection signal is input to the controller **20** according to a predetermined sequence, will the controller **20** determine that the workpiece W has entered the detection area of the light curtain. The controller **20** then starts the muting operation, sends a muting start command to the light receiving unit **14**, and turns on an indicator lamp (not shown) to show that the muting operation is now being performed.

Upon receiving a muting start command from the controller **20**, the light receiving unit **14** uses the information in the light receiving data register **33** which is storing the light incidence/light block information for each optical path and the information in the muting area register **34** to determine whether any optical path other than the muting area is in a light incidence state or light block state. The light receiving muting then outputs the determination result to the controller **20**.

The controller **20** turns the output from the output circuit **42** on and off according to the light incidence/light block information in any area other than the first muting area.

When a muting area switching signal from the sequencer **55** is input to the controller **20**, the controller **20** determines whether or not the signal input to the controller **20** is correct according to the above-described procedure. The controller **20** then transfers the information regarding the second muting area stored in the nonvolatile memory **44** to the muting area register **34** of the light receiving unit **14**. While the data is being transferred and is being verified, namely, the muting area register **34** of the light receiving unit **14** is being updated, all of the optical paths enter a muting operation state.

When the information in the muting area register **34** of the light receiving unit **14** is changed to that related to the second muting area, the light receiving unit **14** determines whether any optical path other than the second muting area is in a light incidence state or light blocked state. The light receiving unit **14** then the outputs this determination to the controller **20**.

This operation is repeated for the predetermined light block substance or workpiece W having portions with different heights as shown in FIG. **1**. When the workpiece W passes through the light curtain, the muting function only becomes effective in the muting area based on the height of the workpiece W. This is the area limited to the optical paths blocked by the workpiece W passing through the light curtain. The essential protection function of the multi-optical-path photoelectric safety apparatus **10** is maintained in all other areas. Thus, for example, when an object, such as a human body, enters the light curtain together with the workpiece W, the operation of the pressing machine **11** is forcibly stopped due to the entry of the human body through the light curtain.

For a workpiece or a predetermined light block substance comprising a varied cross section such as cross-sectional area A, cross-sectional area A+B, and the cross-sectional area A in the workpiece transport direction like the workpiece W in FIGS. **1** and **12**A–**12**C, it is possible for a muting area to be set automatically based on its height dimension. When the muting area is switched, all of the optical paths temporarily enter the muting state while the muting area information is being transferred. Then a transition is made to the muting operation for the new muting area. Accordingly, when the muting area is switched, the muting area that is set in the light curtain can be prevented from entering an undefined state.

If a predetermined light block substance or workpiece is used whose shape continuously changes, the number of setup muting areas can be increased almost continuously. This allows the muting area to be changed in response to the shape of the workpiece.

As shown in FIGS. **13** and **14**, two or more predetermined light block substances or workpieces **W1** and **W2** having different height dimensions are transported on the conveyor line **12**. When the first workpiece **W1** passes through the space between the light emitting unit **13** and the light receiving unit **14**, the muting function becomes effective in the first muting area based on the height of the first workpiece **W1**. When the second workpiece **W2** passes through the space between the light emitting unit **13** and the light receiving unit **14**, the muting function becomes effective in the second muting area based on the height of the second workpiece **W2**. Although the muting area may be switched based on a command from the sequencer **55**, it is possible to use a sensor to detect the height of a workpiece. Then a muting area corresponding to the height of the workpiece may be selected based on the information detected by the sensor and the muting function becomes effective in the newly selected muting area.

If an invalid muting area switching signal from the sequencer **55** is input to the controller **20**, and the logic of one of dual signals does not match that of the other signal, it is assumed that the reliability of the whole system is degraded. Then the output from the controller **20** is preferably turned off, the operation of the pressing machine **11** is forcibly stopped, and an error message is displayed.

Since the muting area register **34** and the determination circuit **35** are placed in the light receiving unit **14**, the muting area cannot be defined while muting area change data is being transferred from the controller **20** to the light receiving unit **14** or while data is being verified. As a result, all of the optical paths are temporarily placed in the muting state. However, the light receiving unit **14** is provided with a plurality of muting area registers **43**, whereby it is possible to change the muting area without temporarily placing all of the optical paths in the muting state.

In the embodiment shown, the determination circuit **35** is located in the light receiving unit **14**. This circuit can also be used to provide another function of the light curtain and also may be placed in the controller **20** rather than in the light receiving unit **14**. Likewise, the muting area register **34** may also be placed in the controller **20** rather than in the light receiving unit **14**.

As a further modification, the detection area of the light curtain may be divided into several blocks and a plurality of muting areas defined in each block may be provided. The user may also set any desired muting area or an area in which the muting function is suppressed by an external input. The user may also set a part of the detection area of the light curtain as a muting area. This is done by entering the optical path number for the muting area to be set by an external input means such as a numeric keypad, etc.

A personal computer may also be connected to the controller **20** using a USB, RS232C, RS485, on other connection. This allows the user to specify a part of the detection area of the light curtain as the muting area from the personal computer, thereby setting the muting area.

The preferred embodiments of the present invention have been described primarily using the case where the light emitting element **13** and the light receiving unit **14** are installed across the conveyor line **12**. However, the invention is not limited to this arrangement. For example, this

invention can also be applied where a light curtain is installed so that it surrounds a dangerous source in an apparatus.

It is to be understood that although the present invention has been described with regard to preferred embodiments thereof, various other embodiments and variants may occur to those skilled in the art, which are within the scope and spirit of the invention, and such other embodiments and variants are intended to be covered by the following claims.

The text of Japanese priority application no. 2002-017572 filed Jan. 25, 2002 is hereby incorporated by reference.

What is claimed is:

1. A multi-optical-path photoelectric safety apparatus comprising:

a light emitting unit;

a light receiving unit forming a light curtain with the light receiving unit; and

a muting function for temporarily rendering a protection function of the light curtain ineffective by allowing a predetermined light block substance to pass through the light curtain, wherein the muting function includes defining a muting area where the muting function is performed and the muting area is set to a region of a detection area forming the light curtain and a protection function is performed on a remaining portion of the detection area forming the light curtain, wherein the light emitting unit has a plurality of light emitting elements that are equally spaced from each other and placed in a row, and the light receiving unit is arranged so as to face the light emitting unit, the light receiving unit has a corresponding number of light receiving elements as the number of the light emitting elements, the light receiving elements are equally spaced from each other and are placed in a row, and wherein each of the light receiving elements and a corresponding light emitting element form an optical path for forming the light curtain; and

a display section for displaying whether the muting area is set for each of the optical paths.

2. The multi-optical-path photoelectric safety apparatus according to claim **1**, wherein a plurality of different muting areas are provided, and wherein the muting area that exerts the muting function can be switched among the plurality of different muting areas so as to provide a muting area responsive to a size of the predetermined light block substance.

3. The multi-optical-path photoelectric safety apparatus according to claim **2**, wherein the detection area of the light curtain is divided into predetermined blocks and the plurality of different muting areas are set for each block, and wherein the muting function selects the muting area from the plurality of different muting areas in each predetermined block.

4. The multi-optical-path photoelectric safety apparatus according to claim **1**, wherein the muting area is set by teaching.

5. The multi-optical-path photoelectric safety apparatus according to claim **1**, wherein the muting area is set by an external input means.

6. The multi-optical-path photoelectric safety apparatus according to claim **1**, further comprising:

a storing section for storing information of a plurality of different muting areas for exerting the muting function; and

a muting area switch unit for switching the muting area from among the plurality of different muting areas in the storing section, so as to provide a muting area responsive to a size of a predetermined light block substance.

7. The multi-optical-path photoelectric safety apparatus according to claim **1**, wherein said display section has a plurality of display elements, each of the display elements corresponding to an optical path for displaying whether the optical element is set for each of the optical paths.

8. A multi-optical-path photoelectric safety apparatus comprising:

a light emitting unit having a plurality of light emitting elements equally spaced from each other and being disposed in a row;

a light receiving unit separated from the light emitting unit and having a corresponding number of light receiving elements as the number of the light emitting elements, the light receiving elements being equally spaced from each other and being disposed in a row, and wherein each of the light receiving elements and a corresponding light emitting element form an optical path for forming a light curtain;

a control unit for controlling each of the optical paths to detect entry of a light block substance; and

a muting optical path setting unit for setting a muting function for each of the optical paths for temporarily rendering the protection function of the light curtain ineffective by allowing a predetermined light block substance to pass through the light curtain, wherein the muting optical path setting unit exerts the muting function to define a muting area where the muting function is performed and the muting area is set to a region of a detection area forming the light curtain and a protection function is performed on a remaining portion of the detection area forming the light curtain; and

a display section for displaying whether the muting area is set for each of the optical paths.

9. The multi-optical-path photoelectric safety apparatus according to claim **8**, further comprising:

a storing section for storing information of a plurality of different muting areas for exerting the muting function, the different muting areas being set by the muting optical path setting unit; and

a muting area switch unit for switching the muting area from among the plurality of different muting areas in the storing section, so as to provide a muting area responsive to a size of a predetermined light block substance.

10. The multi-optical-path photoelectric safety apparatus according to claim **8**, wherein said display section has a plurality of display elements, each of the display elements corresponding to an optical path for displaying whether the optical element is set for each of the optical paths.

11. A multi-optical-path photoelectric safety apparatus comprising:

a light emitting unit having a plurality of light emitting elements equally spaced from each other and being disposed in a row;

a light receiving unit separated from the light emitting unit and having a corresponding number of light receiving elements as the number of the light emitting elements, the light receiving elements being equally spaced from each other and being disposed in a row, and wherein each of the light receiving elements and a corresponding light emitting element form an optical path for forming a light curtain;

a control unit for controlling each of the optical paths to detect entry of a light block substance;

a muting area setting unit for setting a muting function for a muting area for temporarily rendering the protection function of the light curtain ineffective by allowing a predetermined light block substance to pass through the light curtain, wherein the muting area setting unit exerts the muting function and the muting area is set to a region of a detection area forming the light curtain and a protection function is performed on a remaining portion of the detection area forming the light curtain; and

a display section for displaying whether the muting area is set for each of the optical paths.

12. The multi-optical-path photoelectric safety apparatus according to claim **11**, further comprising:

a storing section for storing information of a plurality of different muting areas where the muting function can be performed, the different muting areas being set by the muting area setting unit; and

a muting area switch unit for selecting and switching the muting area from among the plurality of different muting area in the storing section, so that a selected muting area is responsive to a size of the predetermined light block substance.

13. The multi-optical-path photoelectric safety apparatus according to claim **11**, wherein said display section has a plurality of display elements, each of the display elements corresponding to an optical path for displaying whether the optical element is set for each of the optical paths.

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